DOCUMENT RESUME

ED 037 090 EM 007 887

AUTHOR Furno, Orlando F.; And Others
TITLE A Three-Year Experimental Study of the Effectiveness of Programmed Instruction in Mathematics. Final Report.
INSTITUTION Baltimore City Public Schools, Md.
SPONS AGENCY Office of Education (DHEW), Washington, D.C. Bureau of Research.
REPORT NO P-OE-S-464
PUB DATE Jan 70
CONTRACT OEC-6-10-246
NOTE 56p.; Appendix pages A1 through A17 removed due to marginal reproducibility of original document

EDRS PRICE EDRS Price MF-$0.25 HC-$2.90
DESCRIPTORS Conventional Instruction, Individual Differences, *Mathematics Instruction, *Programed Instruction, *Program Effectiveness

ABSTRACT

A three-year experimental study was conducted at Northern High School, Baltimore City Public Schools, to gain evidence indicating whether the use of programed instruction or the use of traditional instruction in high school mathematics resulted in greater mastery of subject matter, greater retention of subject matter, and better grades in first-year college mathematics courses. In addition, an investigation was made of the possibility of an association between instructional format and (1) certain mathematical concepts and skills and (2) various personality differences. Differences between the mean scores of the various criterion measures, adjusted for differential effects of mental ability by analysis of covariance, were, for the most part, in favor of the group receiving conventional instruction. Some differences were statistically significant. No pattern of association emerged between personality factors and success with one or the other of the instructional formats. (Author/SP)

FINAL REPORT

Project No. OE S-464

Contract No. OE 6-10-246

A THREE-YEAR EXPERIMENTAL STUDY OF THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Orlando F. Furno
Director of Research and Development
Baltimore City Public Schools

and

William J. Gerardi
Principal
Baltimore Polytechnic Institute
Baltimore City Public Schools

and

Robert W. Armacost
Research Associate
Division of Research and Development
Baltimore City Public Schools

January, 1970

U.S. Department of Health, Education and Welfare
Office of Education
Bureau of Research

FINAL REPORT

Project No. OE S-464

Contract No. OE 6-10-246

A THREE-YEAR EXPERIMENTAL STUDY OF THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Orlando F. Furno

William J. Gerardi

Robert W. Armacost

Baltimore City Public Schools

Baltimore, Maryland

January, 1970

The research reported herein was performed pursuant to contract No. OE 6-10-246 with the Office of Education, U. S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. Department of Health, Education and Welfare
Office of Education
Bureau of Research

TABLE OF CONTENTS

TABLES

TABLES (continued)

APPENDIX

ACKNOWLEDGEMENTS

The authors would like to express sincere appreciation to Miss Gladys Mitchell, Principal of Northern High School, for her support and cooperation with this project. In addition, special recognition is extended to Mrs. Floretta Fyhr, Mathematics Department Head, and Miss June Danaher, mathematics teacher, who were responsible for the day-to-day operation of the project at Northern High School, and without whose efforts this project would not have been possible. The authors would also like to express their genuine appreciation to Dr. Clara E. Grether of the Division of Research and Development for her assistance with the editing of the final report, and to Mr. Carroll L. Lloyd and Mr. Edward W. Riedel and the staff of the Data Center of the Baltimore City Public Schools for help with the data processing.

ABSTRACT

A three-year experimental study was conducted at Northern High School, Baltimore City Public Schools, to gain evidence indicating whether the use of programmed instruction or the use of traditional instruction in high school mathematics resulted in (1) greater mastery of subject matter, (2) greater retention of subject matter, and (3) better grades in first-year college mathematics courses. In addition, an investigation was made of the possibility of an association between instructional format and (1) certain mathematical concepts and skills and (2) various personality differences. Differences between the mean scores of the various criterion measures, adjusted for differential effects of mental ability by analysis of covariance, were for the most part in favor of the group receiving conventional instruction. Some differences were statistically significant. No pattern of association emerged between personality factors and success with one or the other instructional formats. The authors do not feel that the results of this study, or other similar studies reported in the literature, should alone dictate the choice of teaching mode. Other considerations should also influence such decisions.

A THREE-YEAR EXPERIMENTAL STUDY OF THE

EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

INTRODUCTION

The purpose of this study was to compare the effects of programmed instruction and conventional instruction on the teaching of senior high mathematics over a period of three years. The following parameters relating to the two experimental treatments were investigated during the course of the project: (1) mathematical achievement and retention, (2) student differences in personality, temperament, and ability, (3) possible relationships between concepts and skills taught and instructional format, and (4) relative success of the two treatment groups in first-year college mathematics.

A survey of the numerous published studies on programmed instruction indicates that the following kinds of variables have been examined: sequencing, pacing, step size, learning format (program compared to text), difficulty level of materials, appropriateness of subject matter, transfer capability of traditional and conventional instruction, reduction of monotony, concurrent use of teacher and programmed instruction, student personality differences, student intellectual differences, attitudes of students toward programmed instruction, and contents of the comparison test.

Most of the studies investigating instructional format, including the ones focusing specifically on programmed instruction in secondary mathematics, have been of limited duration. Moreover, the majority of these studies have indicated that no significant differences exist on achievement tests and other criterion measures between the experimental groups using programmed instruction and the control groups using conventional instruction. In view of the short

duration of the majority of studies on programmed instruction, the present study was unique in that tenth grade students taking a three-year sequence in mathematics were followed through graduation from high school. In addition, first-year college mathematics grades were obtained for students in both treatment groups who remained in the senior high mathematics program for the entire three years.

PROCEDURE

Research Questions. The aim of the project was to collect and analyze data which would help answer the following questions:

1. Does the use of programmed instruction or the use of traditional instruction result in greater mastery of subject matter as measured by standard mathematics tests?
2. Does the use of programmed instruction or the use of traditional instruction result in greater retention of subject matter as measured by standard mathematics tests?
3. Is there a relationship between success with one or the other instructional format and various student personality differences?
4. Are certain mathematical concepts and skills taught more effectively by the use of one instructional format than the other?
5. Do students using programmed instruction or traditional instruction in high school mathematics obtain better grades in first-year college mathematics courses?

Subjects. A group of students enrolled in the college preparatory curriculum at Northern High School, Baltimore City Public Schools, constituted the population for this study. Northern High School, which enrolled its first senior high school class (Grade 10) in September 1966, was chosen as the setting because the authors felt that the members of a newly formed mathematics department would participate willingly in an instructional research project requiring special teaching arrangements, responsibilities, and the use of new materials.

The Baltimore City Public School System has an open enrollment policy on the secondary level, and therefore tenth grade students who elected the

college preparatory course at Northern were not drawn primarily from any one neighborhood but from the entire city area. A sufficient number of students enrolled to form fifteen classes of tenth grade geometry, these classes being formed as required by the process of individual student scheduling. Of these fifteen classes, two were designated Special College Preparatory and thirteen were designated College Preparatory.

Students who met the following criteria were eligible for enrollment in the Special College Preparatory classes:

1. Possessed an I. Q. score of 110 or above.
2. Scored at least 5 months above grade level in both arithmetic and reading on the ninth grade Stanford Advanced Achievement Tests.
3. Had a general average of 80 or better in major subjects in the ninth grade.
4. Had completed a course in elementary algebra.
5. Had completed Level I of a modern foreign language.
6. Were recommended by their junior high school principal.

Students who met these criteria were eligible for enrollment in regular College Preparatory classes:

1. Had to have an I. Q. test score of 90 or better.
2. Had to have at least an 8.5 grade level achievement test score in both arithmetic and reading (Standard Advanced Achievement Test) administered in the ninth grade.
3. Had to have a general overall average of 70 or better in all major subjects.

Of the fifteen classes enrolled in geometry, five were selected

for inclusion in the experimental group. As a result, one Special College Preparatory and four College Preparatory classes were designated as experimental. From the remaining ten classes, the remaining Special College Preparatory class was designated as control, and four College Preparatory classes out of the remaining nine of these were selected as controls.

Before a student was admitted to an experimental class, written permission was obtained from parents. A letter explaining the program and requesting permission was sent to the parents of each experimental student. All parents granted permission to have their sons or daughters participate in the investigation.

Class Arrangement: The ten classes representing the two treatment groups were taught according to the arrangment shown in Table 1.

TABLE 1

INITIAL ASSIGNMENT OF CLASSES AND TEACHERS

Teacher	Class Curriculum	Section No.	Class Designated as
I. Mrs. Floretta Fyhr	SCP[a]	1	E
	SCP	2	C
	CP[b]	1	C
	CP	2	E
II. Miss June Danaher	CP	3	C
	CP	4	E
	CP	5	C
	CP	7	E
	CP	10	E
III. Mr. L. Burton Walton	CP	11	C

[a] SCP means Special College Preparatory
[b] CP means College Preparatory
NOTE: Class Sections 6, 8, 9, 12, and 13 were designated neither as Control nor Experimental.

Courses and Materials. Students in the experimental group used programmed textbooks throughout high school except in two instances. After careful evaluation of existing textbooks, the members of the Mathematics Department who were responsible for the overall instructional program in mathematics as well as the implementation of the three-year experimental study at Northern High School, concluded that there were no adequate programmed texts available for teaching coordinate geometry (tenth grade) or analytical geometry (twelfth grade). The investigators had the choice of using what were considered inferior programmed texts or using conventional texts, and, thereby introducing an extraneous independent variable into the experiment. An administrative decision, based on a commitment to provide what the teachers and supervisors felt was the best possible instruction in mathematics for their students, resulted in the use of conventional text material in grade ten for a four-week period and in grade twelve for about a six-week period.

During the first year, tenth grade, all experimental students completed the Temac Plane Geometry text. (All Temac Programmed Materials are published by Encyclopaedia Britannica Press). In addition, the students completed the Baltimore City Public Schools Coordinate Geometry text, written in conventional format by William J. Gerardi, Baltimore City Public Schools. About four weeks were devoted to the Coordinate Geometry text. Of the total group, five students also completed the Temac Second Year Algebra text. One pupil completed the Temac Solid Geometry text.

In the eleventh grade, all experimental students completed the Temac Algebra II text and the Temac Trigonometry text.

The programmed texts used during the senior year were Introduction to Probability and Groups and Fields, both written by Earl and published by McGraw Hill; The World of Statistics written by Johnson and Glenn and published by McGraw Hill, and Temac Solid Geometry. In addition, as noted above, a section of

a traditionally written text, Foundations of Advanced Mathematics, written by Kline et al and published by American Book was used to teach analytical geometry. About six weeks were devoted to the teaching of analytical geometry.

The students in the control group were taught using traditional teaching styles, including teacher lecture, question and answer, and class or group discussion. In addition, generous use was made of filmstrips, projectuals, tapes, models, and the blackboard. Textbooks were Geometry, Plane-Solid-Coordinate by Morgan et al; Modern Algebra and Trigonometry by Dolciani et al; and Modern Geometry, Structure and Method by Jurgensen et al, all of which are published by Houghton-Mifflin. In addition, the control group used Foundations of Advanced Mathematics by Kline et al, published by American Book Company.

Implementation of the programmed instruction was essentially the same for all three years of the study. Students advanced at their own rates, but a pacing schedule was set up so that all students would finish the course. Needed review of various areas was provided by the teacher on a small group basis when certain topics had been completed by several students. Students were familiarized with the terminology of modern mathematics through the use of supplemental student handouts.

In the twelfth grade, the forty-two remaining students in the experimental group formed a class which was subdivided into three different ability groups. Subjects studied during the year were solid geometry, groups and fields, probability, statistics, analytical geometry, and college algebra.

The two teachers worked out a team approach which enabled each group to work on a different subject at a given time, following a tentative time schedule. One day a week was set aside for discussion by each group. While one teacher worked with the discussion group, the other answered individual questions from members of the other two groups. The other two days were devoted entirely to individual programmed instruction with any necessary teacher assistance. Even though this three-group approach meant that the teachers had to be prepared to answer questions

on three different subjects just about every day, teachers and students found this method to be the most satisfactory of the three years.

The traditional teaching styles mentioned in connection with the control group were used with the experimental group only for review or clarification where required. The experimental group did not use the blackboard for student work or demonstration. Filmstrips, projectuals, and tapes were used, however, as a change of pace and as supplementary materials.

Data Collection; As may be seen in Table 2, data gathering for this study involved the collection of initial or baseline data, pre-test data, and post-test data for each student in each of the two treatment groups. Scores on the following measures, administered as part of the city-wide testing program, yielded baseline data: (1) Otis Quick-Scoring Mental Ability Test, (2) Stanford Advanced Reading Test, (3) Kelley-Greene Reading Comprehension Test, (4) Durost-Center Word Mastery Test, and (5) Stanford Advanced Arithmetic Test. In addition, the following measures administered especially for the study, yielded additional baseline data: (1) Kuder Preference Record, (2) Thurstone Temperament Schedule, and (3) Scholastic Aptitude Test. A list of the tests and forms of each which were used appears in the Appendix.

Criterion measures yielding data on achievement and retention of content material included: (1) Cooperative Geometry Test, (2) Cooperative Intermediate Algebra Test, (3) Cooperative Trigonometry Test, and (4) the Baltimore City Advanced Mathematics Test. In addition, the following data bearing on the effects of the two treatments were collected: (1) final grade in each mathematics course, and (2) college freshman mathematics grade.

Table 3 lists the sixty-two variables for which data were collected during the first two years of the project. In addition, Table 3 reports means, standard deviations, number of cases, and the difference of means critical ratio for these

variables. (Data on the twenty-six variables comprising the third year and follow-up are reported in Table 9, p. 26.)

In the initial phase of the study, the number of experimental students was 177, and the number of control students was 137. Due to the process of individual

TABLE 2

DATA COLLECTION FOR THREE-YEAR STUDY ON THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Initial Data Collection or Pretests	Intervention	Posttests
<u>Year I, Grade 10, 1965-66</u> Otis Quick-Scoring Test of Mental Ability Stanford Advanced Reading Test Kelley-Greene Reading Comprehension Test Durost-Center Vocabulary Test Stanford Advanced Arithmetic Test Cooperative Geometry (Pretest) Kuder Preference Test Thurstone Temperament Test	TEMAC Plane Geometry <u>or</u> Conventional Plane Geometry	Teacher's Final Grade in Geometry Cooperative Geometry (Posttest)
<u>Year II, Grade 11, 1966-67</u> Cooperative Intermediate Algebra (Pretest) Cooperative Trigonometry (Pretest)	TEMAC Algebra and Trigonometry <u>or</u> Conventional Algebra and Trigonometry	Cooperative Geometry (Retention) Test Cooperative Intermediate Algebra (Posttest) Cooperative Trigonometry (Posttest) Teacher's Final Grade in Intermediate Algebra and Trigonometry
<u>Year III, Grade 12, 1967-68</u> Baltimore City Advanced Mathematics (Pretest)	TEMAC Advanced Mathematics <u>or</u> Conventional Advanced Mathematics	Cooperative Intermediate Algebra (Retention) Test Cooperative Trigonometry (Retention) Test Baltimore City Advanced Mathematics (Posttest) Teacher's Final Grade in Advanced Mathematics Scholastic Aptitude Test
<u>Year IV, Follow-Up</u> ---	---	College Freshman Mathematics Grade, 1st Term College Freshman Mathematics Grade, 2nd Term

student scheduling and the tendency for fewer students to elect the more advanced high school mathematics courses, the number of cases systematically decreased on a yearly basis. Slight variations in numbers of cases within a certain year reflect such circumstances as student absences and necessary student schedule changes.

The scores for the various subtests on the Cooperative Geometry Test, the Cooperative Intermediate Algebra Test, and the Cooperative Trigonometry Test indicate achievement on specific subject matter concepts and skills. A comparison of the scores on these subtests was made to determine whether any mathematical concepts and skills were more effectively taught through either of the two instructional formats.

TABLE 3

A MATRIX OF MEANS, STANDARD DEVIATIONS, NUMBER OF CASES, AND DIFFERENCES OF MEANS FOR EXPERIMENTAL AND CONTROL GROUPS FOR SIXTY-TWO VARIABLES OF THE STUDY ON THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Variable Number and Name	Experimental Group			Control Group			Difference of Means Critical Ratio*	
	Mean	Standard Deviation	Number of Cases	Mean	Standard Deviation	Number of Cases	In favor of Experimental	In favor of Control
Year I, Grade 10, 1965-66								
1. Otis Quick-Scoring Test of Mental Ability	114.65	8.60	168	118.07	7.17	132		3.76
2. Stanford Adv. Reading (Norm 9.0)	9.97	2.55	167	10.52	2.87	136		1.72
3. Kelley-Greene Reading Comprehension	73.48	20.84	170	77.33	19.05	132		1.67
4. Durost Vocabulary Test	76.65	15.94	170	82.14	15.79	133		2.99
5. Stanford Adv. Arithmetic Test (Norm 9.0)	9.58	2.60	167	10.01	2.38	136		1.37
6. Coop. Geom. Pretest Raw Score	5.92	5.61	167	7.92	5.46	133		3.13
Kuder Preference Test								
7. Validity	40.43	4.06	169	39.98	4.14	132	0.94	
8. Outdoor	33.31	13.90	169	33.05	13.05	132	0.16	
9. Mechanical	24.80	11.50	169	27.39	11.88	133		1.91
10. Computational	23.14	8.82	169	24.55	9.58	133		1.32
11. Scientific	35.43	12.85	169	37.95	12.77	133		1.70
12. Persuasive	38.12	10.24	169	39.29	9.87	133		1.01
13. Artistic	27.98	9.97	169	29.71	10.19	133		0.23
14. Literary	19.68	7.90	169	21.83	8.89	132		2.18
15. Musical	14.43	6.50	169	14.97	6.73	132		0.70
16. Social Service	50.25	14.32	169	44.87	15.57	132	3.08	
17. Clerical	49.71	13.30	169	48.58	14.22	132	0.70	
Thurstone Temperament Test								
18. Active	10.09	3.13	177	10.08	3.22	132	0.23	
19. Vigorous	8.23	4.04	177	8.41	4.36	133		0.37
20. Impulsive	11.48	3.10	177	11.56	3.14	133		0.21
21. Dominant	9.47	4.79	177	8.33	4.48	133	2.15	
22. Stable	8.05	3.39	177	7.83	3.15	133	0.59	
23. Sociable	11.55	3.73	177	10.74	3.63	133	1.92	
24. Reflective	6.99	3.28	177	7.56	3.43	133		1.47

TABLE 3 (continued)

A MATRIX OF MEANS, STANDARD DEVIATIONS, NUMBER OF CASES, AND DIFFERENCES OF MEANS FOR EXPERIMENTAL AND CONTROL GROUPS FOR SIXTY-TWO VARIABLES OF THE STUDY ON THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Variable Number and Name	Experimental Group			Control Group			Difference of Means Critical Ratio*	
	Mean	Standard Deviation	Number of Cases	Mean	Standard Deviation	Number of Cases	In favor of Experimental	In favor of Control
25. Teacher's Final Grade, Geometry	76.86	11.05	167	77.73	12.64	137		0.63
26. Coop. Geom. Posttest	17.84	11.48	165	24.55	11.10	137		5.15
27. Theorems and Definitions	7.45	3.08	167	8.19	2.87	137		2.17
28. Non-Numerical Applications	5.68	2.64	167	7.16	3.10	137		4.43
29. Construction	0.32	0.54	167	0.73	0.71	137		5.54
30. Logic and Proof	4.05	3.43	167	5.73	3.49	137		4.21
31. Numerical and Alg. Applications	5.20	3.83	167	7.30	3.42	137		5.04
Year II, Grade 11, 1966-67								
32. Coop. Geom. Retention Test	15.65	8.65	155	21.42	9.60	128		5.26
33. Theorems and Definitions	6.44	2.68	156	7.83	2.69	128		4.34
34. Non-Numerical Applications	4.29	2.42	156	5.45	2.82	128		3.69
35. Construction	0.42	0.56	156	0.61	0.64	128		2.62
36. Logic and Proof	4.43	3.03	156	5.87	3.33	128		3.79
37. Numerical and Alg. Applications	2.76	2.27	156	4.14	2.62	128		4.66
38. Coop. Int. Alg. Pretest	9.81	6.68	108	12.86	6.76	78		3.06
39. Coop. Int. Alg. Posttest	22.85	9.67	103	26.23	8.52	78		2.48
40. Fundamental Operations/Exponents	3.26	0.89	103	3.32	0.79	78		0.47
41. Fundamental Operations/Radicals	2.61	1.63	103	3.28	1.40	78		2.97
42. Graphs, Functions, Relations	5.88	2.08	103	7.40	2.34	78		4.51
43. Quadratic Equations and Theory	2.11	1.35	103	2.24	1.33	78		0.68
44. Progressions	2.11	1.01	103	1.62	0.84	78	2.94	
45. Variations	2.19	0.92	103	2.41	1.11	78		1.39
46. Logarithms	1.51	0.90	103	0.79	1.07	78	4.80	
47. Formulas	2.67	0.91	103	2.73	0.92	78		0.44
48. Verbal Problems	2.56	1.24	103	3.05	1.24	78		2.63
49. Fundamental Operations	1.36	1.03	103	1.74	0.97	78		2.57
50. Miscellaneous Items	1.73	1.11	103	1.79	0.99	78		0.43
51. Coop. Trig. Pretest	1.58	2.23	96	2.79	2.77	76		3.09

TABLE 3 (continued)

A MATRIX OF MEANS, STANDARD DEVIATIONS, NUMBER OF CASES, AND DIFFERENCES OF MEANS FOR EXPERIMENTAL AND CONTROL GROUPS FOR SIXTY-TWO VARIABLES OF THE STUDY ON THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Variable Number and Name	Experimental Group			Control Group			Difference of Means Critical Ratio*	
	Mean	Standard Deviation	Number of Cases	Mean	Standard Deviation	Number of Cases	In favor of Experimental	In favor of Control
52. Coop. Trig. Posttest	7.53	6.54	97	10.50	5.86	70		3.08
53. Definitions and Understandings	4.51	2.11	97	4.93	1.88	70		1.36
54. Logarithms and Use of Table	0.61	0.86	97	1.54	0.89	70		6.35
55. Trigonometry Identities and Equa.	2.56	1.89	97	3.23	2.11	70		2.12
56. Area of Triangle	0.47	0.67	97	0.90	0.68	70		4.01
57. Radian Measure	0.13	0.34	97	0.07	0.26	70	1.36	
58. Laws of Sines and Cosines	0.24	0.47	97	0.11	0.36	70	1.91	
59. Practical Verbal Problems	1.68	1.79	97	1.66	1.27	70	0.10	
60. Teacher's Final Grade, Intermed.Math.	72.35	12.18	100	75.74	13.77	77		1.71
61. Algebra Gain Score[a]	12.94	5.88	100	13.37	6.23	78		0.47
62. Trigonometry Gain Score[b]	5.98	5.58	96	7.61	5.04	70		1.97

[a]Score on posttest minus score on pretest. Variable #39 minus Variable #38.
[b]Score on posttest minus score on pretest. Variable #52 minus Variable #51.
*Critical ratio of 1.96 is significant at .05 level.
Critical ratio of 2.58 is significant at .01 level.

ANALYSIS OF DATA

Years I and II

Comparability of Treatment Groups. The classes constituting each treatment group were selected so that they would be as equivalent as possible. Students were preassigned to these classes according to the requirements of individual student scheduling. It was necessary, therefore, to determine if differences existed between the two treatment groups in academic ability and achievement. As indicated in Table 3, which gives the difference of means critical ratio, the control group obtained higher scores on each of the baseline tests, including the Otis Quick-Scoring Mental Ability Test, the Stanford Advanced Reading Test, the Kelley-Greene Reading Comprehension Test, the Durost Vocabulary Test, the Stanford Advanced Arithmetic Test, and the Cooperative Geometry Pretest. On three of these, the Otis I. Q. Test, the Durost Vocabulary Test, and the Geometry Pretest, the differences were statistically significant at the .01 level. In view of these findings, it is not surprising that at the end of the first year the control group obtained a higher mean score, significant at the .01 level, on the Cooperative Geometry Posttest. Means were significantly higher for each of the five subtests as well as for the total score.

Results of Analysis of Covariance Program. In order to control for possible subject bias resulting from initial differences in the two comparison groups, an analysis of covariance program was written to partial out the effects of one concomitant variable, mental ability as measured by the Otis I. Q. scores. The results of this program, including adjusted means and covariance values, are given in Table 4. A comparison of these means reveals that the differences in favor of the control group on the two baseline measures, the Durost Vocabulary Test and the Cooperative Geometry Pretest, which had been found to be statistically

TABLE 4

COVARIANCE VALUES AND MEANS ADJUSTED FOR ONE CONCOMITANT VARIABLE FOR EXPERIMENTAL AND CONTROL STUDENTS FOR THE FIRST SIXTY-TWO VARIABLES OF THE STUDY ON THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Variable Number and Name	Adjusted Means		Covariance Value (F)	
	Exper.	Control	Means in Favor of Exper.	Means in Favor of Control
Year I, Grade 10, 1965-66				
1. Otis I. Q.				
2. Stanford Advanced Reading	10.14	10.69		4.20+
3. Kelley-Greene Reading Comprehension	75.50	75.10	0.04	
4. Durost Vocabulary Test	78.28	79.99		1.10
5. Stanford Advanced Arithmetic Test	9.78	10.15		1.76
6. Coop. Geom. Pretest Raw Score	6.47	7.23		1.73
Kuder Preference Test				
7. Validity	40.36	40.05	0.37	
8. Outdoor	33.08	33.01	0.00	
9. Mechanical	24.36	27.30		4.39+
10. Computational	22.96	24.67		2.39
11. Scientific	35.26	37.34		1.81
12. Persuasive	37.86	39.64		2.08
13. Artistic	29.84	29.61	0.03	
14. Literary	19.91	21.71		3.16
15. Musical	---[a]	---[a]		-----[a]
16. Social Service	50.05	45.63	5.83+	
17. Clerical	49.48	49.09	0.06	
Thurstone Temperament Test				
18. Active	10.34	9.88	1.56	
19. Vigorous	7.95	8.37		0.77
20. Impulsive	11.47	11.47	0.00	
21. Dominant	9.54	8.33	4.65+	
22. Stable	8.10	7.65	1.25	
23. Sociable	11.50	10.92	1.66	
24. Reflective	7.12	7.30		0.21
25. Teacher's Final Grade, Geometry	78.10	77.30	0.39	
26. Coop. Geom. Posttest	19.48	23.28		11.20**
27. Theorems and Definitions	7.79	7.98		0.34
28. Non-Numerical Applications	5.97	6.90		8.67*
29. Construction	0.29	0.75		41.63**
30. Logic and Proof	4.46	5.40		6.47+
31. Numerical and Alg. Applications	5.60	6.93		10.96**
Year II, Grade 11, 1966-67				
32. Coop. Geom. Retention Test	16.60	20.53		16.34**
33. Theorems and Definitions	6.67	7.64		10.02*
34. Non-Numerical Applications	4.52	5.21		5.82+
35. Construction	0.42	0.60		5.57+
36. Logic and Proof	4.68	5.59		6.15+
37. Numerical and Alg. Applications	2.97	3.96		12.80**

[a]Data not available

TABLE 4 (continued)

COVARIANCE VALUES AND MEANS ADJUSTED FOR ONE CONCOMITANT VARIABLE FOR EXPERIMENTAL AND CONTROL STUDENTS FOR THE FIRST SIXTY-TWO VARIABLES OF THE STUDY ON THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Variable Number and Name	Adjusted Means		Covariance Value (F)	
	Exper.	Control	Means in Favor of Exper.	Means in Favor of Control
38. Coop. Int. Alg. Pretest	10.90	11.46		0.42
39. Coop. Int. Alg. Posttest	24.35	24.46		0.01
40. Fundamental Operations/Exponents	3.33	3.24	0.40	
41. Fundamental Operations/Radicals	2.83	3.03		0.83
42. Graphs, Functions, Relations	6.11	7.14		9.91*
43. Quadratic Equations and Theory	2.22	2.08	0.49	
44. Progressions	2.09	1.52	15.53**	
45. Variations	2.23	2.36		0.65
46. Logarithms	1.58	0.73	31.14**	
47. Formulas	2.74	2.64	0.54	
48. Verbal Problems	2.69	2.90		1.32
49. Fundamental Operations	1.45	1.62		1.30
50. Miscellaneous Items	1.85	1.63	2.19	
51. Coop. Trig. Pretest	1.70	2.63		5.64+
52. Coop. Trig. Posttest	8.25	9.51		1.79
53. Definitions and Understandings	4.68	4.71		0.01
54. Logarithms and Use of Table	0.72	1.47		28.17**
55. Trigonometry Identities and Equa.	2.70	3.05		1.24
56. Area of Triangle	0.48	0.89		12.63**
57. Radian Measure	0.13	0.08	1.20	
58. Laws of Sines and Cosines	0.23	0.12	2.39	
59. Practical Verbal Problems	1.77	1.49	1.20	
60. Teacher's Final Grade, Intermediate Math.	73.06	74.42		0.47
61. Algebra Gain Score	13.46	12.96	0.28	
62. Trigonometry Gain Score	6.69	6.79		0.01

+ Indicates significance at .05 level.
* Indicates significance at .01 level.
** Indicates significance at .001 level.

significant, were no longer so after adjustments were made for differences in I. Q.* The control group, however, retained a significantly higher mean on the total score of the Cooperative Geometry Posttest, which was given at the end of the first year. Significant differences in favor of the control group also held for the following subtests of this measure: Non-Numerical Applications, Construction, Logic and Proof, and Numerical and Algebraic Applications.

Further examination of Table 4 shows that during the second year of the project, the control group obtained a significantly higher mean on the Cooperative Geometry Retention Test which was administered early in the school term. On the Cooperative Intermediate Algebra Posttest, given in the middle of the year, significant differences in favor of the control group were found on the Graphs, Functions, Relations subtest. Significant differences in favor of the experimental group were found on the Progressions and Logarithms subtests. No significant difference was found between the comparison groups on the basis of the total scores on this test. Again, on the Cooperative Trigonometry Posttest, given at the end of the second year, significant differences in favor of the control group were found on the Logarithms and Use of Table and Area of Triangle subtests, although no significant difference was found between the comparison groups on the total scores for this test.

In only two instances were adjusted means on the criterion measures administered during the first and second years of the project found to be in favor of the experimental group. Significant differences were obtained for the experimental group on the Progressions and Logarithms subtests of the Cooperative Intermediate Algebra Posttest. On several measures, moreover, small apparent differences did not turn out to be statistically significant. At the end of the first year, there was no significant difference between the comparison groups on the basis of the teacher's final grades in Geometry. During the second year, no statistically

*Due to the fact that the n's for the analysis of covariance program differed slightly from the n's used in the computation of the difference of means critical ratio, an apparent difference on the Stanford Advanced Reading Test in favor of the control group became a statistically significant difference.

significant difference was found between the groups on the total Cooperative Intermediate Algebra Posttest score. Similarly, no statistically significant difference was found on the total Cooperative Trigonometry Posttest score, even though a significant difference was obtained in favor of the control group on the Trigonometry Pretest. No statistically significant differences were found, moreover, between the Teachers' Final Grades in Intermediate Mathematics or between the Algebra Gain Scores or the Trigonometry Gain Scores.

Summary of Pretest, Posttest, and Retention Test Differences on Adjusted Means. A summary of pretest, posttest, retention test, and mean difference comparisons on the Cooperative Geometry, Cooperative Intermediate Algebra, and Cooperative Trigonometry tests is provided in Tables 5, 6, and 7. Significant differences were found in favor of the control group on the Geometry Posttest and Retention Test, as well as the Intermediate Algebra Retention Test. Apparent, but not significant, differences were obtained in favor of the control group on the Intermediate Algebra Posttest, the Trigonometry Posttest, and the Trigonometry Retention Test. These results should be interpreted with the knowledge that the number of cases for the variables studied changed over time and also with the appreciation that the groups were comparable but not totally equivalent with respect to ability and achievement.

Comparison of Characteristics of High Achieving and Low Achieving Experimental Students. In order to investigate the possible existence of differences of intellect, temperament, and disposition between high and low achieving students using programmed instruction in mathematics, scores obtained by experimental students on the Cooperative Geometry Posttest were arranged by computer from highest to lowest. Next, the scores for the 25th and 75th percentiles were computed. A score below 7 on the Geometry Posttest caused a student to be placed in the lowest quartile, whereas a score of 26 or better caused a student to be placed in the highest quartile grouping. There were 37 students placed in the highest quartile

TABLE 5

COOPERATIVE GEOMETRY TEST: PRETEST, POSTTEST, AND RETENTION TEST DIFFERENCES ON ADJUSTED MEANS

$M_{E1}=$ 6.47	$D_1=$ 0.76 NS	$M_{C1}=$ 7.23
$D_E=$ 13.01	$D_C-D_E=$ 3.04*	$D_C=$ 16.05
$M_{E2}=$ 19.48	$D_2=$ 3.80*	$M_{C2}=$ 23.28
$M_{E3}=$ 16.60	$D_3=$ 3.93*	$M_{C3}=$ 20.53

TABLE 6

COOPERATIVE INTERMEDIATE ALGEBRA TEST: PRETEST, POSTTEST, AND RETENTION TEST DIFFERENCES ON ADJUSTED MEANS

$M_{E1}=$ 10.90	$D_1=$ 0.56 NS	$M_{C1}=$ 11.46
$D_E=$ 13.46	$D_E-D_C=$ 0.50 NS	$D_C=$ 12.96
$M_{E2}=$ 24.35	$D_2=$ 0.11 NS	$M_{C2}=$ 24.46
$M_{E3}=$ 23.37	$D_3=$ 8.01*	$M_{C3}=$ 31.38

<u>Key</u>:

E=experimental group
C=control group
M_1=pretest
M_2=posttest
M_3=retention test
D=difference or gain

* designates significance at .001 level.
NS designates no significance.
NOTE: Pretest and posttest means as well as mean differences have been computed on available data, and accordingly, the n's vary slightly. Retention test n's vary to a greater extent. The n's for all variables are given in Table 3, p. 11 and Table 9, p. 26.

TABLE 7

COOPERATIVE TRIGONOMETRY TEST: PRETEST, POSTTEST, AND RETENTION TEST DIFFERENCES ON ADJUSTED MEANS

$M_{E1}=$ 1.70	$D_1=$ 0.93 +	$M_{C1}=$ 2.63
$D_E=$ 6.69	$D_C-D_E=$ 0.10^{NS}	$D_C=$ 6.79
$M_{E2}=$ 8.25	$D_2=$ 1.26^{NS}	$M_{C2}=$ 9.51
$M_{E3}=$ 3.31	$D_3=$ 1.22^{NS}	$M_{C3}=$ 4.53

Key:

E=experimental group
C=control group
M_1=pretest
M_2=posttest
M_3=retention test
D=difference or gain

+ designates significance at .05 level.
NS designates no significance.

NOTE: Pretest and posttest means as well as mean differences have been computed on available data, and, accordingly, the n's vary slightly. The n's for all variables are given in Table 3, p.11 and Table 9, p. 26.

TABLE 8

A MATRIX OF MEANS, STANDARD DEVIATIONS, NUMBER OF CASES AND DIFFERENCES OF MEANS FOR THE HIGHEST AND LOWEST QUARTILES OF THE EXPERIMENTAL GROUP, YEAR I, 1965-66, THIRTY-THREE VARIABLES[1]

Variable Number and Name	Highest Quartile of Experimental Group			Lowest Quartile of Experimental Group			Difference of Means Critical Ratio[2]	
	Mean	Standard Deviation	Number of Cases	Mean	Standard Deviation	Number of Cases	In favor of Top 25%	In favor of Lowest 25%
Year I, Grade 10, 1965-66								
1. Otis I. Q.	121.00	7.82	37	109.74	7.06	35	6.421	
2. Stanford Adv.Reading	11.16	0.94	37	9.33	2.57	35	3.977	
3. Kelley-Greene Rdg. Comp.	85.43	13.61	37	62.21	23.33	34	5.067	
4. Durost-Center Voc. Test	84.89	10.58	37	68.94	18.56	34	4.397	
5. Stanford Adv.Arith.Test	10.61	2.02	37	8.86	2.43	35	3.304	
6. Coop. Geom.Pretest Raw Sc.	10.31	5.84	36	2.18	3.05	34	7.360	
Kuder Preference Test								
7. Validity	41.14	2.32	36	41.30	2.29	37		-0.293
8. Outdoor	37.14	12.51	36	35.24	13.95	37	0.612	
9. Mechanical	24.42	11.04	36	29.24	13.35	37		-1.685
10. Computational	23.72	11.02	36	21.54	7.00	37	1.006	
11. Scientific	34.92	14.84	36	38.05	13.34	37		-0.949
12. Persuasive	36.11	12.38	36	39.54	9.62	37		-1.319
13. Artistic	29.69	10.13	36	29.16	8.47	37	0.243	
14. Literary	19.97	7.39	36	17.60	6.91	37	1.419	
15. Musical	14.94	6.45	36	14.95	7.32	37		-0.001
16. Social Service	49.33	15.24	36	48.54	12.86	37	0.240	
17. Clerical	49.83	14.97	36	50.81	12.27	37		-0.305
Thurstone Temperament Test								
18. Active	10.35	2.66	37	9.92	3.12	39	0.645	
19. Vigorous	7.73	3.44	37	9.21	4.64	39		-1.581
20. Impulsive	10.62	3.72	37	11.56	2.91	39		-1.227
21. Dominant	8.60	4.75	37	8.95	4.47	39		-0.334
22. Stable	8.27	3.69	37	7.28	3.31	39	1.228	
23. Sociable	11.14	4.59	37	11.26	3.28	39		-0.132
24. Reflective	7.57	3.58	37	6.80	3.12	39	1.001	

TABLE 8 (continued)

A MATRIX OF MEANS, STANDARD DEVIATIONS, NUMBER OF CASES AND DIFFERENCES OF MEANS FOR THE HIGHEST AND LOWEST QUARTILES OF THE EXPERIMENTAL GROUP, YEAR I, 1965-66, THIRTY-THREE VARIABLES[1]

Variable Number and Name	Highest Quartile of Experimental Group			Lowest Quartile of Experimental Group			Difference of Means Critical Ratio[2]	
	Mean	Standard Deviation	Number of Cases	Mean	Standard Deviation	Number of Cases	In favor of Top 25%	In favor of Lowest 25%
25. Teacher's Final Grade, Geometry	86.30	8.75	37	67.56	9.06	39	9.171	
26. Coop. Geom. Posttest	33.95	7.30	37	3.85	2.45	39	23.854	
27. Theorems & Definitions	11.00	1.65	37	3.91	1.79	39	17.978	
28. Non-Numerical Applications	8.74	1.73	37	3.09	1.89	39	13.590	
29. Construction	0.33	0.45	37	0.26	0.50	39	0.580	
30. Logic and Proof	7.99	3.76	37	1.52	1.58	39	9.678	
31. Numerical and Algebraical Appl.	9.35	2.53	37	1.42	2.30	39	14.279	

[1]Upper and lower quartiles were formed on the basis of Cooperative Geometry Posttest Raw Scores, Variable 26.
[2]Critical ratio of 1.96 indicates significance at .05 level.
Critical ratio of 2.58 indicates significance at .01 level.

and 39 students placed in the lowest quartile. High scoring and low scoring geometry students were compared with respect to the 33 variables studied. The results of this comparison are given in Table 8.

As expected, those students in the highest quartile scored significantly better on the Otis Quick-Scoring Test of Mental Ability, the Stanford Advanced Reading Test, the Kelley-Greene Reading Comprehension Test, the Durost-Center Vocabulary Test, the Stanford Advanced Arithmetic Test, and the Cooperative Geometry Pretest. Differences were significant beyond the .01 level of confidence.

On four of the five subtests of the Cooperative Geometry Posttest, significant differences were obtained in favor of the experimental students comprising the highest quartile. On the fifth subtest, however, Construction, no significant difference was found between the top scoring and low scoring groups.

It had been anticipated that differences in personality and disposition might exist between high and low scoring students as measured by the Kuder Preference Test and the Thurstone Temperament Test. This was not the case. No significant differences emerged between these two groups on any of the areas surveyed by the Kuder Preference Test: Outdoor, Mechanical, Computational, Scientific, Persuasive, Artistic, Literary, Musical, Social Service, and Clerical. Likewise, no significant differences emerged between the two groups on any of the areas surveyed by the Thurstone Temperament Test, including the following categories: Active, Vigorous, Impulsive, Dominant, Stable, Sociable, and Reflective.

Comparison of Experimental and Control Groups Psychological Test Variables. In an attempt to investigate the possiblity of an association between various learner characteristics as measured by the Kuder Preference Test or the Thurstone Temperament Test and success with either of the two instructional formats used in the project, differences in scores on these instruments were compared by means of

a critical ratio. As shown in Table 3, p.11, the only significant differences between the two groups on the Kuder Preference Test were a social service preference in the experimental group and a literary preference in the control group. Table A15 (Appendix, p. A 1) indicates that although a significant negative correlation appeared between the experimental group social service preference and the experimental group Cooperative Trigonometry Pretest, no meaningful pattern was established between this particular trait, or any other, and the mathematics achievement tests. As regards the control group, Table A16 (Appendix, p. A 6) indicates that no pattern of significant correlation was established between literary preference and the mathematics achievement tests.

On the basis of the Thurstone Temperament Test scores, the only significant difference in personality between the two treatment groups was in the area of dominance, in the direction of the experimental group. No significant correlation or pattern of association was established between this particular trait, or any other trait measured by the test, and the mathematics achievement tests administered during the project.

Relationships Between Experimental Variables. Pearson product-moment correlation coefficients were computed for all sixty-two variables of the first two years of the project. These correlation coefficients for the experimental and control groups are reported in Tables A15 and A16 (Appendix, pp. A1 -A9.) In both treatment groups, as would be expected, a pattern of positive correlation was established between I. Q. scores and mean mathematics achievement test scores, particularly those obtained on the posttests. Generally, somewhat lower correlations appeared between mean I. Q. scores and teachers' final grades in Geometry and Intermediate Mathematics.

In both of the treatment groups a pattern of positive correlation was established between the mean scores of the various standardized tests given to measure

mastery of subject matter. Correlation coefficients were again higher for posttest comparisons. Moreover, a fairly consistent relationship was established between mean scores on the standardized posttests and teachers' final grades.

Year III.

Size and Comparability of Treatment Groups at the Beginning of Year III. During the final phase of the project, data were collected for thirty-six additional variables for those students who remained in the experimental mathematics program at Northern High School for the third year. Forty-two students of the original experimental group studied Advanced Mathematics using programmed instruction. Thirty-six students of the original control group studied Advanced Mathematics using conventional instruction.

The mean I. Q. score for the remaining experimental students was 115.43; the standard deviation was 8.54. The mean I. Q. score for the remaining control students was 119.50; the standard deviation was 5.42. The difference between the means of the two groups was significant at the .05 level.

The variable names and numbers as well as means and standard deviations for both treatment groups for Year III are reported in Table 9. As indicated in this table, the experimental group obtained a higher unadjusted total mean score on the Baltimore City Advanced Math Pretest. On the Baltimore City Advanced Math Posttest, however, results were in favor of the control group. In addition, there was an apparent difference in favor of the control group in the amount of progress made in twelfth grade mathematics, as revealed by the Advanced Math Gain Score and the Teacher's Final Grade in Advanced Math.

Results of Analysis of Covariance Program. In order to control for subject bias resulting from the effects of differences in mental ability, the analysis of covariance program used to analyze the data for Years I and II, was again run for selected variables of Year III. The results of this program, including

TABLE 9

A MATRIX OF MEANS, STANDARD DEVIATIONS, AND NUMBER OF CASES FOR EXPERIMENTAL AND CONTROL GROUPS FOR THE FINAL THIRTY-SIX VARIABLES OF THE STUDY ON THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Variable Number and Name	Experimental Group			Control Group		
	Mean	Standard Deviation	Number of Cases	Mean	Standard Deviation	Number of Cases
Year XII, Grade 12, 1967-68						
63. Coop. Int.Alg.Ret.Test,Fm.Z,Raw Sc.	22.54	8.65	41	32.31	6.00	32
64. Scaled Score	58.80	5.68	41	63.94	2.45	32
65. Percentile	56.29	21.70	41	75.66	9.06	32
66. Fund. Oper. with Exp.	3.02	0.99	42	3.60	0.49	35
67. Fund. Oper with Radicals	2.98	1.32	42	4.91	1.05	35
68. Graphs, Functions, Relation	5.71	1.82	42	6.66	1.82	35
69. Quadratic Equa. and Theory	1.33	1.17	42	2.69	1.12	35
70. Progressions	1.69	0.77	42	1.71	0.70	35
71. Variations	2.21	1.01	42	2.20	1.09	35
72. Logarithms	1.00	0.84	42	1.83	0.84	35
73. Verbal Problems	2.76	0.87	42	3.14	0.83	35
74. Fund. Operations	2.83	1.38	42	3.29	1.00	35
75. Misc. Items	1.40	0.82	42	2.11	0.71	35
76. Coop.Trig.Ret.Test, Fm.Y, Raw Sc.	3.17	2.66	42	4.64	3.38	36
77. Scaled Score	43.24	6.56	42	46.17	6.37	36
78. Percentile	9.98	9.34	42	16.00	13.10	36
79. Appli.of Basic Def.&Unders.	2.86	1.55	42	2.94	1.78	36
80. Logarithms and Use of Table	0.78	0.67	42	1.14	1.00	36
81. Trig. Identities and Equa.	1.43	1.42	42	1.25	1.06	36
82. Area Triangle	0.14	0.35	42	0.64	0.63	36
83. Radian Measure	0.67	0.74	42	0.50	0.76	36
84. Laws of Sines and Cosines	0.14	0.41	42	0.08	0.28	36
85. Practical Verbal Problems	1.52	1.35	42	1.60	1.36	35
86. Balto.City Adv.Math Pre-Test,Raw Sc.	6.64	2.88	42	6.50	3.23	34
87. Balto.City Adv.Math Post-Test,RawSc.	8.81	3.19	42	11.57	2.85	35
88. Analytics	2.83	1.19	42	4.37	1.80	35
89. Adv. Alg.	1.55	1.18	42	3.54	1.27	35
90. Prob. and Statistics	1.83	1.15	42	0.69	0.82	35
91. Three Dimensional Geometry	2.07	1.24	42	2.37	0.99	35
92. Groups and Fields	0.50	0.66	42	0.40	0.54	35

TABLE 9 (continued)

A MATRIX OF MEANS, STANDARD DEVIATIONS, AND NUMBER OF CASES FOR EXPERIMENTAL AND CONTROL GROUPS FOR THE FINAL THIRTY-SIX VARIABLES OF THE STUDY ON THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Variable Number and Name	Experimental Group			Control Group		
	Mean	Standard Deviation	Number of Cases	Mean	Standard Deviation	Number of Cases
93. Balto.City Adv. Math Gain Score[a]	2.64	2.82	42	5.26	3.72	34
94. Teacher's Final Grade, Adv. Math.	80.52	6.54	42	84.47	8.36	30
95. Scholastic Aptitude Test Score	515.74	84.10	38	576.53	57.25	30
96. College Math Grade, 1st Term	2.60	0.71	15	2.86	0.81	22
97. College Math Grade, 2nd Term	2.75	0.66	16	2.62	0.93	16
98. Math Power Score[b]	6.68	4.46	22	10.73	6.79	22

[a] Score on posttest minus score on pretest. Variable #87 minus #86.

[b] Math Power Score equals assigned difficulty index of course multiplied by value of grade earned.

adjusted means and covariance values, are given in Table 10. The findings with regard to the Cooperative Intermediate Algebra Retention Test and the Cooperative Trigonometry Retention Test have already been discussed above under Analysis of Data: Years I and II, p. 18. With regard to the criterion measures relevant to mastery of subject matter taught during Year III, the following observations, summarized in Table 11, may be made. On the basis of adjusted means there was no statistically significant difference between the treatment groups on the Baltimore City Advanced Mathematics Pretest. The differences between the two groups on the Advanced Mathematics Posttest and the Mathematics Gain Score, however, were determined to be statistically significant ones in favor of the group receiving conventional instruction.

Relationships Between Variables Within the Experimental Group. Pearson product-moment correlations were computed for the twenty-six variables of the final phase of the study. These correlation coefficients for the experimental and control groups are reported in Tables A17 and A18 (Appendix, pp. A10-A 17). In the experimental group, significant positive correlations appeared between the baseline I. Q. measure and the tests used to evaluate retention of subject matter, the Cooperative Intermediate Algebra Test and the Cooperative Trigonometry Test. I. Q. was also significantly correlated with the teachers' final grades in Advanced Math and the Scholastic Aptitude Test scores. I. Q. scores were not significantly correlated with the Baltimore City Advanced Math Pretest or Posttest scores, but they were significantly correlated with the Baltimore City Advanced Math Gain scores.

In a number of instances there were significant positive relationships between both Retention Tests, Intermediate Algebra and Trigonometry, and the standardized tests of mathematics given during Years I and II of the study. Furthermore, the Intermediate Algebra Retention Test, but not the Trigonometry Retention Test, however, correlated significantly with the Scholastic Aptitude Test. There was no significant pattern of association established between the Baltimore City

TABLE 10

COVARIANCE VALUES AND MEANS ADJUSTED FOR ONE CONCOMITANT VARIABLE FOR CONTROL AND EXPERIMENTAL STUDENTS FOR TEN SELECTED VARIABLES OF YEAR III OF THE STUDY ON THE EFFECTIVENESS OF PROGRAMMED INSTRUCTION IN MATHEMATICS

Variable Number and Name	Adjusted Means		Covariance Value (F)	
	Exper.	Control	Means in Favor of Exper.	Means in Favor of Control
Year III, Grade 12, 1967-68				
63. Coop. Int. Alg. Ret.Test,Fm.Z,Raw Sc.	23.37	31.38		20.82**
76. Coop. Trig.Ret.Test, Fm.Y, Raw Score	3.31	4.53		2.84
86. Balto.City Adv. Math Pretest, Raw Sc.	6.51	6.78		0.13
87. Balto.City Adv. Math Posttest, Raw Sc.	8.83	11.64		14.19**
93. Balto.City Adv.Math Gain Score	2.79	5.09		8.76*
94. Teacher's Final Grade,Adv.Math.	80.88	83.40		1.67
95. Scholastic Aptitude Test Score	523.50	564.83		5.35+
96. College Math Grade, 1st Term	2.66	2.91		0.84
97. College Math Grade, 2nd Term	2.77	2.65		0.15
98. Math Power Score	7.06	10.89		4.33+

+Indicates significance at .05 level.
*Indicates significance at .01 level.
**Indicates significance at .001 level.

Advanced Mathematics Pretest or Posttest scores and the scores on the baseline measures or the criterion measures.

A pattern of significant correlation was established between the Scholastic Aptitude Test and the majority of standardized tests used as baseline measures or criterion measures.

No meaningful pattern of association was established between the subtests of the Kuder Preference Test or the Thurstone Temperament Test and the variables related to mastery of subject matter. Thus, no meaningful patterns of association were found to exist in the experimental group between various vocational preferences or qualities of disposition and variables measuring mastery of subject matter.

<u>Relationships Between Variables Within the Control Group</u>. Table A18 (Appendix, p. A14) indicates that, contrary to the results obtained for the experimental group, no significant correlations appeared in the control group between the baseline I. Q. measure and any of the standardized tests administered during

TABLE 11

BALTIMORE CITY ADVANCED MATHEMATICS TEST: PRETEST AND POSTTEST DIFFERENCES ON ADJUSTED MEANS

$M_{E1}=$ 6.51	$D_1=$ 0.27^{NS}	$M_{C1}=$ 6.78
$D_E=$ 2.79	$D_C-D_E=$ 2.30*	$D_C=$ 5.09
$M_{E2}=$ 8.83	$D_2=$ 2.81**	$M_{C2}=$ 11.64

<u>Key</u>:

E=experimental group
C=control group
M_1=pretest
M_2=posttest
D=difference or gain

NS designates no significance.
* designates significance at .01 level.
** designates significance at .001 level.

NOTE: Pretest and posttest means as well as mean differences have been computed on available data, and, accordingly, the n's vary slightly.

Year III of the project. In other words, a relationship which had obtained for both treatment groups for Years I and II of the project and for Year III for the experimental group, did not hold for Year III for the control group. Examination of the mean I. Q. scores and standard deviations recorded for those students remaining in the program, as reported above on p. 25, indicates that the control students had a significantly higher mean I. Q. and a lower standard deviation. A manual check on the data revealed that when scores on two variables, for example, I. Q. scores and Scholastic Aptitude Test scores, were both consistently high, opportunities for correlation between scores were reduced. At the upper end of the scale, certain of these measuring instruments are apparently

limited in ability to discriminate with the precision needed to develop significant correlations.

With regard to the Retention Tests, significant positive correlations appeared between the Intermediate Algebra Test, but not between the Trigonometry Test, however, and the standardized tests of mathematics given during Years I and II of the study. Both of these Retention Tests correlated significantly with the Scholastic Aptitude Test.

There was no pattern of significant correlation established between the Baltimore City Advanced Mathematics Pretest or Posttest and the baseline measures, including I. Q. There was a pattern established, however, between the Baltimore City Advanced Mathematics Posttest and the majority of criterion measures for all three years.

No meaningful pattern of association was established between the subtests of the Kuder Preference Test or the Thurstone Temperament Test and the variables related to mastery of subject matter.

College Follow-Up

Choice of College. At the close of the academic year 1968-69, a questionnaire was mailed to each graduate of Northern High School who participated in all three years of the study. (See Appendix, p.A22 for a sample questionnaire). Students who did not reply to the initial request for information on college mathematics courses and grades were asked a second time to supply this information. Of the forty-two experimental students, thirty-eight (90%) responded the first semester, and thirty-four (81%) responded the second semester. Of the thirty-six control students, thirty-five (97%) responded the first semester, and thirty-one (86%) responded the second semester. Rate of response, therefore, was a little higher both semesters for the control students.

As shown in Table 12, thirty-five experimental students, or 88% of those

TABLE 12

SUMMARY OF COLLEGES ATTENDED BY EXPERIMENTAL AND CONTROL STUDENTS

College	No. of Experimental Students Attending	No. of Control Students Attending
Bennington College (Vt.)		1
Brown University (R. I.)		1
College of Notre Dame of Maryland (Md.)		1
Community College of Baltimore (Md.)	5	4
Elizabethtown College (Pa.)		1
Frostburg State College (Md.)	3	1
Georgia Institute of Technology (Ga.)		1
Goucher College (Md.)	1	
Indiana University (Ind.)		1
Loyola College (Md.)	1	
Mt. St. Agnes College (Md.)	2	
Muhlenburg College (Pa.)	1	
St. John's, Annapolis (Md.)	1	
St. Mary's College of Maryland (Md.)	1	
Towson State College (Md.)	12	9
Trinity College (Conn.)		1
Union Memorial Hospital School of Nursing (Md.)	1	
University of Maryland (Md.)	4	7
University of Pennsylvania (Pa.)		1
Villa Julie (Md.)	1	
Western Maryland College (Md.)	2	3

Treatment Group Comparisons	Experimental Students	Control Students
No. of Students Responding Either Semester	40	35
No. of Students Attending College	35	32
No. of Different Colleges	13	13
No. of Out-of-State Colleges	1	7

who responded either semester, reported attendance at thirteen different colleges. Of these thirteen institutions, twelve were located within the state of Maryland; one was located outside the state. Thirty-two control students, or 91% of those who responded either semester, reported attendance at thirteen different colleges. Of these thirteen institutions, six were located within the state of Maryland; seven were located outside the state. In summary, a slightly higher percentage of control students reported college attendance. Moreover, more control students attended colleges out of the state of Maryland than did experimental students.

Courses Taken and Grades Earned. Tables 13 and 14 report the semester courses taken and grades earned by the students in the two treatment groups. These courses were arbitrarily categorized as Elementary Level Courses, Statistics Courses, or Intermediate and Advanced Level Courses. Each of these three categories was assigned a difficulty rating. Grades earned in each course were given numerical point values and these values were multiplied by the course difficulty rating.

As reported in Table 10, p. 29, the control group obtained a significantly higher mean mathematics power score. On the basis of this variable and from inspection of the data reported in Tables 13 and 14, it appears that the thirty-two control students who attended college took somewhat more difficult college mathematics courses and earned somewhat higher grades than the thirty-five experimental students attending college.

TABLE 13

SUMMARY OF COURSES TAKEN AND GRADES EARNED BY EXPERIMENTAL STUDENTS

Elementary Level Courses (Difficulty Rating =1)	No. of Semester Courses	Grades A	B	C	D
Basic Concepts of Mathematics	1		1		
Elements of Mathematics	4	1	2	1	
Fundamental Concepts of Mathematics	2		2		
Fundamentals of Arithmetic	1		1		
Fundamentals of Mathematics	1		1		
Introduction to Mathematics	6	1	1	4	
Mathematics--An Elementary Approach	1		1		
	Total 16				
Courses in Statistics (Difficulty Rating=2)					
Probability and Statistics	2		1	1	
Statistics	2		1	1	
	Total 4				
Intermediate and Advanced Level Courses (Difficulty Rating=3)					
Algebra	2	1		1	
Algebra and Trigonometry	2		1	1	
Analysis I	1		1		
Calculus I	1				1
Finite Mathematics	1			1	
Intermediate Algebra	1		1		
Mathematical Analysis (Pre-Calculus)	1		1		
Modern Mathematics	1		1		
	Total 10				
Other (Difficulty Rating=2)					
Euclid-Ptolemy	1			1	
	Total 1				

NOTE: Course titles are those supplied by students.

TABLE 14

SUMMARY OF COURSES TAKEN AND GRADES
EARNED BY CONTROL STUDENTS

	No. of Semester Courses	Grades A	B	C	D
Elementary Level Courses (Difficulty Rating=1					
Basic Concepts of Arithmetic	1		1		
Elements of Mathematics	5		2	3	
Fundamentals of Mathematics	2	2			
General Mathematics	1		1		
Introduction to Mathematics	2			2	
Total	11				
Courses in Statistics (Difficulty Rating=2)					
Modern Elementary Statistics	1	1			
Modern Elementary Statistics and Probability	1		1		
Probability Functions	1			1	
Statistics	1			1	
Total	4				
Intermediate and Advanced Level Courses (Difficulty Rating=3)					
Algebra and Trigonometry	4	1	1	2	
Analytic Geometry	3		1	2	
Calculus I	2			2	
Calculus II	2			1	1
Calculus and Analytic Geometry	4	2		2	
Differential Calculus	1	1			
Elementary Functions	1		1		
Integral Calculus	2	1	1		
Introductory Analysis	2	2			
Modern Mathematics	1		1		
Total	22				

NOTE: Course titles are those supplied by students. The control group was credited with an additional unnamed course for which a grade of "C" was given.

DISCUSSION AND CONCLUSIONS

Mastery of Subject Matter

Does the use of programmed instruction or conventional instruction in high school mathematics result in greater mastery of subject matter as measured by standard mathematics tests? At the end of the first year of the study the group receiving conventional instruction obtained a significantly higher mean (adjusted by analysis of covariance to control for differential effects of mental ability) on the Cooperative Geometry Posttest as reported in Table 5, p. 19. The difference between the mean gain scores computed on the basis of Cooperative Geometry Pretest and Posttest comparisons was a significant one in favor of the control group.

During the second year the control group obtained higher adjusted means on the Cooperative Intermediate Algebra Posttest and the Cooperative Trigonometry Posttest, as reported in Table 6, p. 19 and Table 7, p. 20. The differences between the means for the two groups, however, were not statistically significant. The experimental group obtained a slightly higher adjusted mean gain score on the basis of Cooperative Intermediate Algebra Pretest and Posttest comparisons, but the difference between the groups was not statistically significant. The control group obtained a slightly higher adjusted mean gain score on the basis of Cooperative Trigonometry Pretest and Posttest comparisons, but again the difference between the two groups was not statistically significant.

At the end of the third year, as indicated in Table 11, p. 30, the control group obtained a statistically significant higher adjusted mean score on the Baltimore City Advanced Mathematics Posttest. The control group also obtained a statistically significant higher mean gain score on the basis of Baltimore City Advanced Mathematics Pretest and Posttest comparisons.

While the empirical evidence for the first year and the third year seems to lend support to the hypothesis that conventional instruction is more effective

than programmed instruction, a visual examination of the mean standardized test scores, as well as the teachers' final grades, as reported in Table 4, p. 15 and Table 10, p. 29, reveals that most of the obtained differences were small ones. Such small differences, even when statistically significant, may not be critical ones from a practical or operational standpoint. On the assumption that for all practical purposes programmed instruction proved as effective as conventional instruction, other considerations should influence the choice of teaching method.

Does the use of programmed instruction or the use of traditional instruction result in greater retention of subject matter as measured by standardized tests? On the tests measuring retention of subject matter, all differences were in favor of the control group, as reported in Tables 5 and 6, p. 19; Table 7, p. 20; and Table 11, p. 30. Differences were statistically significant on the Cooperative Geometry Retention Test and on the Cooperative Intermediate Algebra Retention Test, but not on the Cooperative Trigonometry Retention Test. Again, it may be relevant to ask if these differences are important and practical ones in a real teaching situation.

It is possible that uncontrolled variables operated to prevent greater differences from developing between the two instructional groups on the criteria of mastery and retention of subject matter. The following issues relate to the research problem of uncontrolled variables: (1) How equivalent was the content presented in the programmed format and the conventional format? A difference in content might have worked to the advantage or disadvantage of either group. (2) Because the public schools have a responsibility to parents and students to provide the most effective teaching possible for all individuals, it was necessary, as mentioned above, to make administrative decisions, which, while helping to insure excellence of instruction, may have resulted in the confounding of the independent variables. These decisions involved the use of conventionally written

text materials with the experimental group for a total period of about ten weeks over the three-year study, and the supplementary individual and small group instruction which was generally provided to all students in both treatment groups who required such help.

A caveat is entered in the interpretation of the results of this experiment. The authors have attempted to apprise the reader of certain operational aspects of the study which might have influenced results. Any attempt to generalize from these findings should take into consideration the fact that the experiment took place in a real teaching situation, which made it difficult to maintain rigid control over the application of the treatments being compared.

Is there a relationship between success with one or the other instructional format and various student personality differences? The basis for answering this research question is not taken to be individual instances of association between personality traits or vocational preferences and scores on the various criterion measures. Rather, the investigators looked for the emergence of a consistent pattern of association. The possibility of such a pattern of association was investigated first among the high achieving and low achieving students within the group using programmed instruction. Second, the possibility of such a pattern of association was investigated among the students within each treatment group. No conclusive pattern of association developed in either of these two cases between the items measured by the Thurstone Temperament Test or the Kuder Preference Test and the various criterion measures.

As reported in the correlation matrices, Tables A15, p. A1; A16, p. A6; A17, p. A10; and A18, p. A14, significant correlations did appear rather consistently between the baseline measures, including the measures of mental ability and achievement in reading and arithmetic, and the standardized tests used to measure mastery and retention of subject matter. Thus, on the basis of these results, one would conclude that ability and achievement levels are more reliable predictors of

success, with either instructional method, than are factors of personality and disposition.

Are certain mathematical concepts and skills taught more effectively by the use of one instructional format than the other? Generally, if total mean scores on the standardized tests were in favor of one or the other group, the subtest mean scores on these tests followed the same pattern. Some exceptions may be noted; e. g., the control group obtained a statistically significant higher adjusted total mean score on the Baltimore City Advanced Mathematics Posttest, as reported in Table 10, p. 29, whereas the experimental group obtained a higher mean on the Probability and Statistics subtest. Several other instances of particular concepts and skills which seem to have been taught more effectively by programmed instruction may be noted in Table 4, p. 15 and Table 9, p. 26. Because the results were not conclusive, the authors feel that this question deserves further investigation.

Do students using programmed instruction or traditional instruction in high school mathematics obtain better grades in first-year college mathematics courses? The Scholastic Aptitude Test was administered to both treatment groups at various times during the final year of the study. On this measure of general ability and achievement related to academic success on the college level, the control group obtained a significantly higher adjusted mean. This test serves the purpose of an additional baseline measure, rather than a measure of mastery or retention of subject matter. On the basis of the results of the baseline measures given initially to the original group of 177 experimental students and 137 control students, as well as the results of the Scholastic Aptitude Test given to the remaining forty-two experimental students and thirty-six control students, one might question the equivalence of the two groups both during the early stage and final stage of the study. Although differences in intelligence as measured

by the Otis Quick-Scoring Test of Mental Ability were controlled for by analysis of covariance, the authors feel that the results should be interpreted with the knowledge that subject bias resulting from the effects of differential achievement levels may have worked to the disadvantage of the group receiving programmed instruction.

As reported in Table 13, p. 34 and Table 14, p. 35, it appears that the control group took more advanced mathematics courses in the first year of college and earned better grades. Whether this is a result of the conventional instruction that these students experienced in high school is not clear. A rival hypothesis to the one claiming an empirical relationship between mastery of subject matter and conventional instruction would be that the students who elected to remain in the more advanced, traditionally taught mathematics courses were more earnest mathematics students and had the benefit of greater ability and achievement in mathematics.

Observations and Conclusions of Teachers. In the opinion of the teachers who participated in the experiment, students using programmed instruction achieved at about the same levels as comparable students using conventional instruction. This observation held for the understanding of theory as well as the mastery of mechanics.

Feedback from students indicated that they generally found long stretches of straight programmed instruction boring. Related to this finding were two others concerning interest and motivation. The teachers did not feel that more interest in mathematics was developed by one method than by another. Moreover, while some students using programmed instruction were motivated to move ahead faster than required, the majority were content to stay on schedule.

The teachers expressed a belief that well-written programmed texts not only provided for differences in learning rates, but allowed teachers to get to know students and their learning styles much better. This led to the

development of more rapport between students and teachers than is possible in a class using conventional instruction. Other positive benefits came from the increased responsibility for learning that programmed instruction placed on the students. Both the teachers and the students felt that this increased self-discipline would help them adjust to the requirements of college.

Finally, weighing the advantages of programmed texts and conventional texts, the teachers agreed that programmed texts would be most valuable when used as part of a total course or program of instruction or as a supplement to conventional instruction.

IMPLICATIONS

The results of this study lend a degree of support to the hypothesis that different teaching methods, namely, programmed instruction and conventional instruction, do appear to have statistically significant effects on the learning and retention of secondary mathematics, as measured by standardized tests of subject matter. Although the treatment group receiving conventional instruction appeared to achieve in a fashion superior to that of the group receiving programmed instruction, the authors do not believe that the relative effectiveness and value of the two teaching methods has been conclusively established by this or other similar studies reported in the literature.

There is first the question of the practical and operational importance of modest differences, which may nonetheless prove to be statistically significant. There is, in addition, the issue of intervening variables which at once contribute to the reality and naturalness of the experimental setting and which pose problems for experimental design.

In conclusion, the authors feel that school systems wishing to try out programmed materials on various levels and subjects should not be held back because the relative effectiveness of the two teaching modes has not been authoritatively established. They should, however, choose programmed materials which promise to produce results at least as good, from a practical standpoint, as conventional materials. In addition, other considerations such as the cost of programmed materials, preparedness and ability of teachers to use teaching materials, and student ability levels should influence such decisions. Finally, school systems should consider the possibility of using a variety of instructional teaching modes and approaches for component skill and content areas within a particular subject.

APPENDIX

Not Included

APPENDIX

List of Testing Instruments Used

a) Otis Quick-Scoring Mental Ability Tests (Gamma Test: Form AM)

by Arthur S. Otis

b) Stanford Achievement Test (Advanced Battery Partial: Form KM)

by Truman L. Kelley
Richard Madden
Eric F. Gardner
Lewis M. Terman
Giles M. Ruch

c) Kelley-Greene Reading Comprehension Test (Form BM)

by Victor H. Kelley
Harry A. Greene

d) Durost-Center - Word Mastery Test (Form AM)

by Walter N. Durost
Stella S. Center

e) Cooperative Plane Geometry Test (Form Z)

by Educational Testing Services, Princeton, N. J.

f) Kuder Preference Record - Vocational (Form CM)

by G. Frederic Kuder

g) Thurstone Temperament Schedule

by L. L. Thurstone

h) Cooperative Intermediate Algebra Test - Quadratics and Beyond (Form Z)

by Educational Testing Services, Princeton, N. J.

i) Cooperative Trigonometry Test (Form Y)

by Educational Testing Services, Princeton, N. J.

APPENDIX

List of Testing Instruments Used

j) Baltimore City Advanced Mathematics Test

by Baltimore City Department of Mathematics

k) Scholastic Aptitude Test

by College Entrance Examination Board

APPENDIX

Sample of Letter Sent to Parents of Experimental Students

October 7, 1965

To the parents of ______________________:

It is a pleasure to inform you that your (son, daughter) has been selected to participate in a special mathematics program which is to be conducted at Northern High School during the next three years. Programmed mathematics instructional textbooks and materials are to be used in this program. Programmed textbooks enable each pupil to progress at his optimal learning rate in mathematics. Capable pupils will have an opportunity to obtain instruction in mathematics courses beyond those which are normally obtainable at the senior high school level. The program will also provide an opportunity for individual pupils to spend additional time on essential topics and units which may be difficult for them. Pupils will receive a great deal of individual help and attention from the teacher because the programmed materials give the teacher greater freedom and more time to help individuals.

All pupils who enter the program will continue their study of geometry with programmed geometry textbooks. As soon as a pupil satisfactorily completes the programmed geometry course he will commence a study of programmed second year algebra. Subsequent courses, which pupils may study after successfully completing geometry and second year algebra include: analytic trigonometry, solid geometry, probability, statistics, modern algebra, differential calculus, and integral calculus. All pupils will not be expected nor required to complete all of the aforementioned courses.

APPENDIX

Sample of Letter Sent to Parents of Experimental Students

You will be interested to know that the programmed mathematics textbooks which are to be used in this program have been used successfully by high school pupils in other cities, other states, and in other Baltimore City schools since 1960. Many of these pupils have been successful in gaining advanced standing in mathematics in college.

If you want to have your (son, daughter) participate in the special mathematics program described above please read, check the appropriate box, and sign the attached form. Please return the completed and signed form via your son or daughter to Mrs. Floretta Fyhr, mathematics department head at Northern High School, by October 13, 1965.

Gladys Mitchell, Principal

APPENDIX

Mathematics Department
Northern High School
2201 Pinewood Avenue
Baltimore, Maryland 21214

Dear Graduate:

As a follow-up for the programmed instruction experimental program in mathematics at Northern High School, in which you participated as a student in either a programmed or control class, it is imperative that we know what you are doing now.

If you are in college, please give the name of the college, the exact title of any mathematics course you have taken this first semester and the grade earned.

Your anticipated cooperation in this matter is sincerely appreciated. Thank you so much for your help.

Sincerely,

(Mrs.) Floretta Fyhr

(Miss) June Danaher

pal

- -

Tear off and return to Northern High School in the envelope provided.

Place of full-time employment____

OR

College____

Math course in college____
(If you are not taking a mathematics course, write the word "None.")

Grade earned____________

Your name____

Number____________________________